PLANT SUCCESSION ON SICILIAN TERRACES

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ABSTRACT - 189 phytosociological relevés have been made in five areas of Sicily, three on volcanic substrates and two on limestones, to study plant community succession trends within abandoned terraced vineyards and cereal fields. Disturbance status and abandonment age was recorded for each sample plot. DCA of these relevés suggests that four are the most important factors driving succession, i.e. geological substrate, bioclimate, age of abandonment and disturbance. In most cases - if there are some dispersal centres near the old fields - undisturbed and less disturbed terraces evolve quite rapidly towards the local potential "climax" community. Different trends have been recorded on the areas which underwent and still undergo frequent and severe disturbance: succession is biased or even blocked in a steady state, so that grassland, garrigue, mantle or herb-dominated communities prevail. The species composition of the plant communities subject to disturbance seems to be strongly connected with the time gap between abandonment and first disturbance occurrence. The "mixed" ecological-structural-phytosociological approach here adopted to describe plant communities was quite effective to interpret abandoned terraces communities and their dynamism.

KEY WORDS – Abandonment, Disturbance, Fire, Grazing, Old fields, Secondary succession

INTRODUCTION

Like many other European agricultural landscapes, cultivated terraces have been subject to abandonment during the last century, as they often cannot host modern mechanized agriculture. With abandonment starts secondary succession on these peculiar old fields. Aim of this paper is to provide some clues on the dynamic trends, the floristic composition and the species-richness of the plant communities currently present in Sicilian terraced landscape, which some recent studies were focused on (Richter, 1989; Rühl, 2004; Rühl, Pasta and La Mantia, 2005; Rühl, Pasta and Schnittler, 2006; AA. VV., 2007).

Since fire and grazing disturbance is very frequent in Sicily, with our study we also tried to investigate to what extent these factors influence abandoned terraces' vegetation features.

Material and Methods

Study areas

Terraced landscapes characterize nearly 3% of the whole Sicilian surface (AA. VV., 2007); they are rather common on Aeolian Islands, Palermo Mts., Etna region, Pantelleria Island, Hyblaean Plateau, Peloritani Mts. (NE Sicily) and Erei Mts. (Central-SE inner Sicily). To verify the role played by substrate on vegetation features (species composition and richness, structure and dynamics) we have chosen our sample plots only in the first five areas (Fig. 1): Hyblaean Plateau and Palermo Mts. are dominated by limestones, while Aeolian Islands, Pantelleria and Etna are constituted by volcanic substrata. The first two couples of areas share more or less the same bioclimatic features, while Etna terraces cover a wider bioclimatic range (Tab. 1).

Data sampling

The vascular plant communities growing within the level terrace surface of the selected sample plots have been checked through vegetation relevés based on the Zürich-Montpellier phytosociological method (Braun-Blanquet, 1964). Plants' presence and cover was recorded for each layer. Braun-Blanquet's scale was used for cover values under 5%, while higher cover values were carefully calculated, with a precision degree of 1% for cover values 5÷15% and of 5% for cover values >15%.

Only abandoned vineyards or grain crop fields were selected as sample plots, while all abandoned olive groves and fruit orchards have been excluded, as it can be hypothesized that secondary succession processes are modified by the presence of

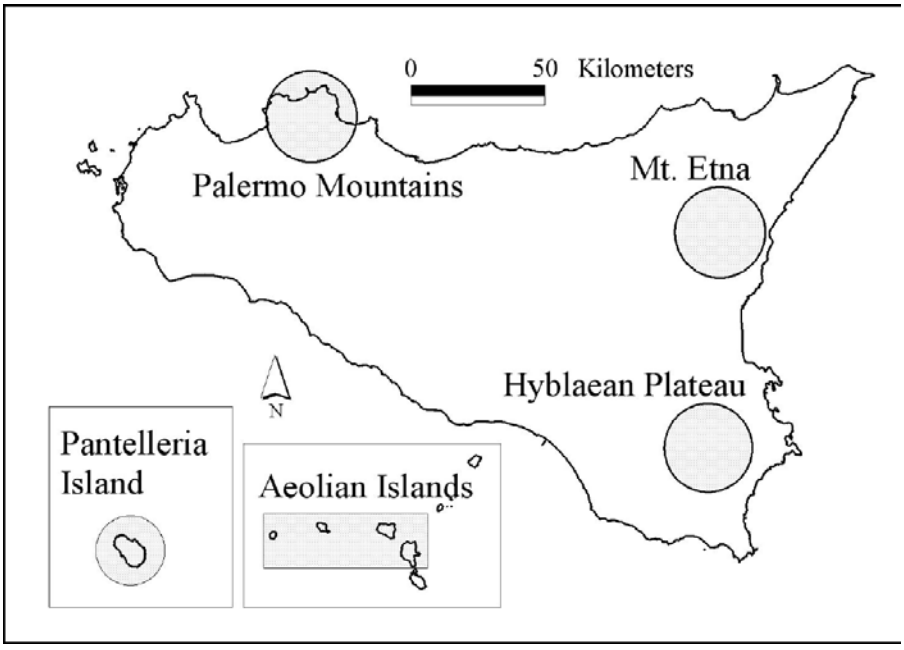

Figure 1 - Location of the five study areas.

TABLE 1 - Main abiotic (soil; altitude range; bioclimate after Cartabellotta, Drago, Lo Bianco and Lombardo, 1998) and biotic (potential vegetation) characteristics of the five study areas. M = Palermo Mts., H = Hyblaean Plateau, A = Aeolian Islands, P = Pantelleria, E = Etna, L = deriving from limestones; V = deriving from volcanic rocks; SM = Supramediterranean; MM = Mesomediterranean; TM = Thermomediterranean; l = low; u = upper; s = subhumid; h = humid.

Area	Soil	altitude range (m a.s.l.)	Bioclimate		local potential "climax"		
			Thermo-type	Ombro-type	(class)	(order)	(alliance)
M	L	315-825	MM	u-s	*Quercetea ilicis*	*Quercetalia ilicis*	*Quercion ilicis*
				l-s			
			TM	u-s		*Quercetalia calliprini*	*Oleo-Ceratonion*
				l-s			
H	L	280-740	MM	l-s	*Quercetea ilicis*	*Quercetalia ilicis*	*Quercion ilicis*
				u-a			
			TM	l-s		*Quercetalia calliprini*	*Oleo-Ceratonion*
A	V	50-525	TM	l-s	*Quercetea ilicis*	*Quercetalia calliprini*	*Oleo-Ceratonion and/or Ericion arboreae*
				u-a			
P	V	170-470	TM	u-a	*Quercetea ilicis*	*Quercetalia calliprini*	*Oleo-Ceratonion and/or Ericion arboreae*
E	V	530-1505	SM	u-s	*Querco-Fagetea*	*Quercetalia pubescenti-petraeae*	*Pino-Quercion congestae*
			MM	l-h	*Quercetea ilicis*	*Quercetalia ilicis*	*Erico-Quercion ilicis*
				l-s			
				u-s			

trees within an old field. Selected sample plots were always 50 sqm-sized to allow data comparison. Plant classification was mostly based upon Pignatti (1982) and Tutin, Heywood, Burges, Valentine, Walters and Webb (1964-1980). The author(s) of plant names are mentioned only at the first quotation.

In the five study areas we made 189 relevés both on North-facing and on South-facing slopes. Apart from the typical abiotic data such as exposition, altitude, etc., also disturbance evidences were recorded. Therefore, it was possible to ascribe the relevés to four categories differing for their "disturbance status" (presence/absence and nature of disturbance): burnt (F), grazed (P), cultivated (C) and undisturbed plots

(U). Category "F" included all the plots where carbonized stems, resprouted plants or local people interviews allowed us to verify that at least one fire has really affected them. Relevés have been made only where fire occurred at least five years ago. Category "P" grouped all those relevés where grazing has been and still is a strong disturbance factor. Grazing was verified by directly observing feeding animals (cattle, sheep or goats) or their excrements. It has to be underlined that disturbance by grazing includes very often also disturbance by fire, since herdsmen burn pastures to keep them clear from shrubs and to favour the resprouting of bunchgrasses (Guarino, 2006). Category "C" included all the still cultivated sample plots, namely vineyards or grain crops. Finally, all the plots where the above mentioned disturbance factors were absent have been referred to Category "U".

For every sample plot, abandonment age was checked through aerial photographs of the years 1955, 1968, 1987, 1992, 2000 and 2002. In this way, plots were attributed to abandonment age classes: Class 1 = still cultivated today; Class 2 = still cultivated in 2002, thus abandoned less than 4 years ago; Class 3 = still cultivated in 1987, thus abandoned about 5-20 years ago; Class 4 = still cultivated in 1968, thus abandoned about 20-40 years ago; Class 5 = still cultivated in 1955, abandoned about 40-50 years ago; Class 6 = already abandoned in 1955, thus abandoned about more than 50 years ago.

Data Evaluation

Species cover values <5% were transformed following van der Maarel (1979). Multivariate analysis was used to identify environmental factors accounting for most of the variance within the vegetation data. A data set including all vegetation relevés was analysed with DCA, using CANOCO 4.0 (ter Braak & Smilauer, 2002). The resulting axes were subsequently correlated to environmental data, namely a) bioclimate (Thermo- and Ombrotype), b) abandonment age, c) disturbance status, d) geological substrate and e) exposition. The same data set of vegetation relevés was also analysed by TWINSPAN, which is a hierarchical, divisive, polythetic combination of ordination and classification (Kent & Coker, 1992; Glavac, 1996).

Sample plot groups (= clusters) resulting from DCA and TWINSPAN were then used for a better interpretation of plant communities and to check the dynamic relations between them. As plants are (prevalently) linked to only one phytosociological class, a thorough analysis of their presence and cover in the plots falling within each group may allow the phytosociological interpretation of the plot groups themselves. Nevertheless, secondary succession within abandoned terraces often is such a chaotic process (both in chronological and microtopographical terms) that it is quite common to encounter a complex patchwork of different vegetation units formed by different guilds (= functional plant groups) co-occurring on the same terrace. Thus, to succeed in our "translation effort" and sketch a physiognomic synthesis of each plot, we also used the available information on vegetation structure (dominance, cover percentage of perennial herbs and woody species) and on the phytosociological meaning of each recorded plant (to the alliance level, if possible). The following description of the single clusters uses some thresholds of shrub and tree cover to describe vegetation structure: when tree cover >70%, then it was called "closed woodland", if <70% "open woodland". We named "mantle" the plant communities dominated by broadleaved summergreen tall shrubs and/or by shrubby Fabaceae and

Rosaceae, while we used the terms "shrubland" and/or "maquis" for tall shrub-dominated communities and "garrigue" for subshrub-dominated ones; when the woody cover of these communities was >80%, we called them "closed", when it was 60-80%, they have been indicated as "± closed", when <60%, we used the term "patchy vegetation made up of ... (= list of the other plant communities in order of cover) with ... (= dominant woody vegetation)". The plots dominated by perennial grasses were called "grasslands", if only by therophytes or biennal hemicryptophytes they were defined "herbs". Moreover, to reinforce our interpretation, all the most relevant literature on the vegetation dynamics (Poli Marchese, Di Benedetto and Maugeri; 1988; Cullotta & Pasta, 2004) and the pre-forest and forest vegetation of the study areas (Poli Marchese & Maugeri, 1975; Brullo, Di Martino and Marcenò, 1977; Marcenò & Colombo, 1982; Di Benedetto, 1983; Ferro, 1984, 2005; Brullo & Marcenò, 1985b; Bartolo, Brullo, Minissale and Spampinato, 1992; Marcenò & Ottonello, 1993; Minissale, 1995; Brullo, Scelsi, Siracusa and Spampinato, 1999; Brullo, Minissale and Siracusa, 1998; Ferro & Ladero-Alvárez, 1999; Gianguzzi, 1999) has been consulted. The syntaxonomic treatment of the coenoses quoted in text mostly follows Brullo, Giusso Del Galdo, Minissale, Siracusa and Spampinato (2002). The author(s) of each syntaxon are mentioned only at first quotation.

Results

Eigenvalues of the first three axes of DCA are 0.744, 0.633 and 0.455; total inertia is 19.7.

The correlation of the environmental data with the ordination results of DCA shows that axis 1 is correlated with abandonment age (correlation coefficient r = -0.71), axis 2 with geological substrate (r = -0.63), disturbance status (r = -0.54), bioclimate (r = -0.84) and abandonment age (r = -0.72), and axis 3 with geological substrate (r = 0.87). Thus, these four factors have to be taken into consideration to explain relevé clustering. Two conclusions can be drawn from DCA sample ordination plot: first, relevés clump from warmer conditions in the upper left to colder conditions in the lower right (Fig. 2). Second, the influence of abandonment age is strongly depending upon disturbance status: undisturbed young succession stages clump on the upper right and old succession stages on the lower left of the sample ordination plot, while some grazed relevés are situated in the centre even if abandoned more than 50 years ago (see arrow in Fig. 3).

From DCA and TWINSPAN resulted 14 clusters of relevés (Fig. 4). Although every cluster shows quite a distinct identity when described through the above mentioned "multiple" approach, some of them do not match perfectly with pure phytosociological units, not only for the patchy habit of the vegetation of several plots, but also because many plants, which are considered characteristic of one single class at the European level, in Sicily behave as transgressive within different phytocoenoses. As dominant species are listed those species which were found at least in one sample plot with >10% cover.

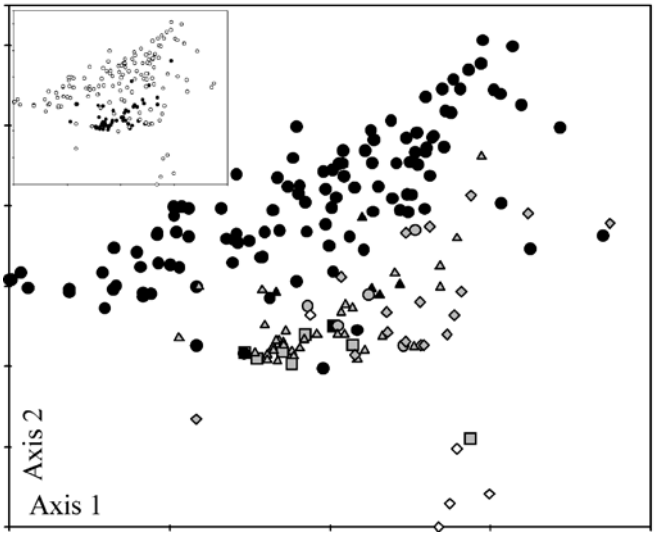

FIGURE 2 - DCA of vegetation data: sample ordination diagram (axes 1 and 2). Every relevé is represented by a symbol corresponding to its thermotype (full symbols = Thermomediterranean, grey symbols = Mesomediterranean) and its ombrotype (circle = upper arid, triangle = low subhumid, square = upper subhumid, diamond = low humid); empty diamonds = Supramediterranean upper subhumid. The eigenvalue of axis 1 is 0.744, while that of axis 2 is 0.633. Inset: the same ordination, but symbols showing the substrate of each plot. Empty circles represent volcanic substrates, full ones limestones.

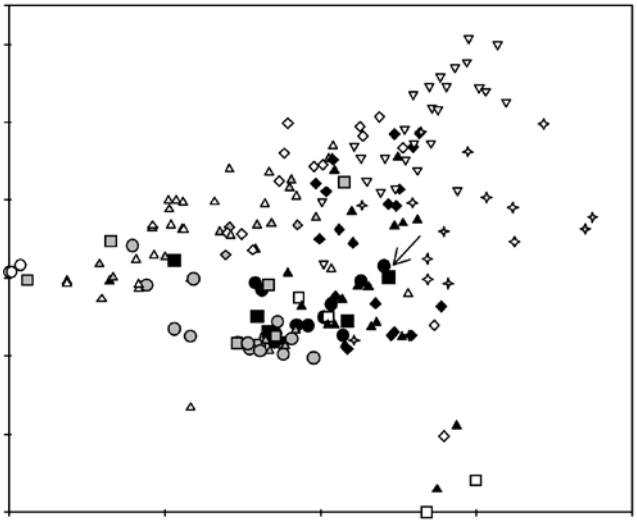

FIGURE 3 - DCA of vegetation data: sample ordination diagram (axes 1 and 2). Every relevé is represented by a symbol corresponding to its disturbance status (empty symbols = U, except for empty star = C; grey symbols = F; full symbols = P), combined with abandonment age (circle = abandoned prior to 1955; square = abandoned between 1955 and 1968; triangle-up = abandoned between 1968 and 1987; diamond = abandoned between 1987 and 2002; triangle-down = abandoned after 2002). The eigenvalue of axis 1 is 0.744, while that of axis 2 is 0.633.

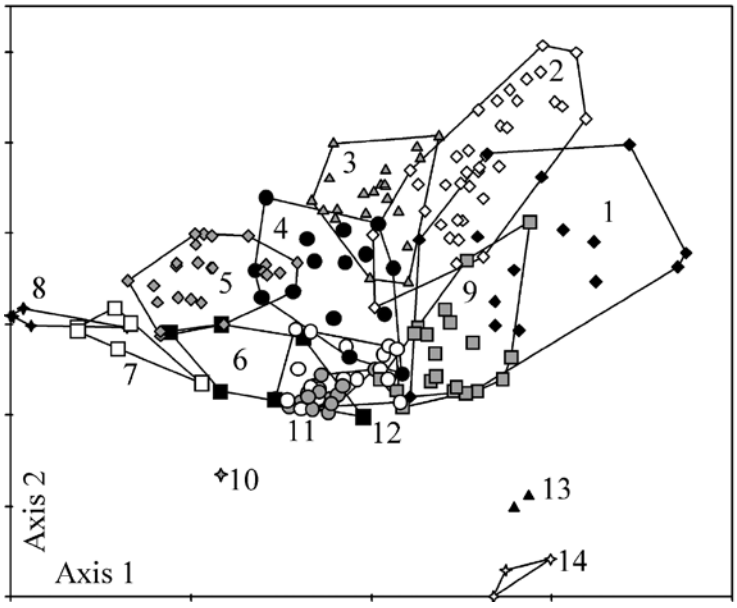

FIGURE 4 - The 14 clusters of vegetation relevés resulting from DCA and from TWINSPAN drawn in the sample ordination diagram (axes 1 and 2) of DCA. The eigenvalue of axis 1 is 0.744, while that of axis 2 is 0.633. Cluster 1 = full diamond, Cl. 2 = empty diamond, Cl. 3 = grey triangle, Cl. 4 = full circle, Cl. 5 = grey diamond, Cl. 6 = full square, Cl. 7 = empty square, Cl 8 = full star, Cl. 9 = grey square, Cl. 10 = grey star, Cl. 11 = grey circles, Cl. 12 = empty circles, Cl. 13 = black triangle, Cl. 14 = empty star.

Cluster 1 includes almost all still cultivated terraces (15 relevés); 7 of them have been made on Pantelleria and Aeolian Islands volcanic substrates under Thermo-mediterranean (TM)-upper (u)-arid (a), 4 on the vulcanites of Mt. Etna under Meso-mediterranean (MM)-low (l)-humid (h), 4 on limestone under MM-l-subhumid (s) (Hyblaean Plateau) climate. All terraces in this cluster are characterized by herbs with not more than 5% of woody cover. Clearly dominant species are totally absent; only two perennial herbs [*Lobularia maritima* (L.) Desv. and *Cyperus rotundus* L.] and few therophytes occasionally cover more than 20% of the cultivated fields. All these nitrophilous annual communities are referred to *Stellarietea mediae* R. Tx. et al. ex von Rochow 1951; more precisely, the relevés made on the vineyards of Mt. Etna, Pantelleria and Aeolian Archipelago should be ascribed to *Fumarion wirtgenii-agrariae* Brullo 1985 (Brullo & Marcenò, 1985a), while those taken in the cereal crop fields of Hyblaean Plateau pertain to *Roemerion hybridae* Br.-Bl. ex Rivas-Martínez et al. 1999.

Cluster 2 includes 36 relevés made on the volcanic islands of Pantelleria (33) and Aeolian Archipelago (3), mostly under TM-u-a climate. Most of these terraces are undisturbed since their abandonment (within the last 5 years), 9 have been abandoned between 1968 and 2000 and then underwent grazing disturbance. These fallows are characterized by herbs, more often with about 5% (rarely 10-15 and only once up to 25%) woody cover (especially *Rubus ulmifolius* Schott). Clearly dominant are nitrophilous annual (and even biennial) herbs typical to *Echio-Galactition tomentosae* O. de Bolòs et Molinier 1969 (Brullo, 1983).

Cluster 3 includes 21 plots, 20 on vulcanites (Pantelleria: 14, Aeolian Islands: 6) and only one on Hyblaean limestones, all subject to TM climate (mostly u-a). Among the terraces, 11 undisturbed and 7 grazed were abandoned between 1968 and 2000; the other three were abandoned at least 20 years ago and underwent wildfires. The terraces are characterized by patchy vegetation dominated by perennial grasses and/or herbs with mostly 5-15% (rarely up to 50%) woody cover. The dominant species are *Hyparrhenia hirta* (L.) Stapf, *Andropogon distachyos* L., *Rubus ulmifolius*, *Cistus* spp. and *Artemisia arborescens* L.. Although no clear syntaxonomical interpretation is possible, the prevailing feature is a perennial thermo-xerophilous grassland ascribed to *Hyparrhenion hirtae* Br.-Bl., P. Silva et Rozeira 1956, often accompanied by shrubs linked to disturbed and nutrient-rich conditions (*Rubus ulmifolius* and *Artemisia arborescens*) or typical to *Cisto-Ericion multiflorae* Horvatič 1958, such as *Cistus* spp., and/or by a high number of *Stellarietea mediae* herbs. In some cases the low number of woody species might depend upon the position of the plots, set in areas with no (few, species-poor and/or distant) pre-forest and forest vegetation nuclea.

Cluster 4 includes 15 sample plots on volcanic substrates. 13 of them (Pantelleria: 10, Aeolian Islands: 3) are subject to TM-u-a, the other two (Mt. Etna) to MM-l-h and Supramediterranean (SM)-u-s climate. Among the terraces abandoned at least 20 years ago, 4 are undisturbed, 3 are burnt and 3 are grazed, while those abandoned between 1987 and 2000, 1 is undisturbed, 2 are burnt and 2 are grazed. The physiognomy of the phytocoenoses included within this cluster appear heterogenous: 7 samples show a patchy vegetation made up of perennial grasses and/or herbs with woody cover of 40-70%; open (4 samples) and dense (5 samples) shrublands/maquis communities characterize the remaining plots. The dominant species are *Piptatherum miliaceum* (L.) Cosson, *Hyparrhenia hirta*, *Andropogon distachyos*, *Ampelodesmos mauritanicus* (Poir.) T. Durand et Schinz, *Pteridium aquilinum* (L.) Kuhn, *Spartium junceum* L., *Cytisus villosus* Pourr., *Rubus ulmifolius*, *Pistacia lentiscus* L., *Cistus* spp., *Artemisia arborescens*, *Phillyrea latifolia* L. Even if the plots are quite homogeneous concerning substrate, bioclimate and abandonment age, it sounds quite difficult either to evaluate disturbance role or to interpret their phytosociological meaning: in fact, species-poor or even monospecific shrubby layers, mostly characterized by woody species typical to mantle (*Pruno-Rubion ulmifolii* O. de Bolòs 1954), to maquis (*Oleo-Ceratonion siliquae* Br.-Bl. ex Guinochet et Drouineau 1944 em. Rivas-Martínez 1975) or even to garrigue (*Cisto-Ericion multiflorae*) communities, often coexist with few perennial grassland (mostly *Hyparrhenion hirtae*) and many nitrophilous therophytes. This cluster probably represents the natural evolution of cluster 3 under light disturbance and shows some structural and floristic similarities with cluster 5.

Cluster 5 includes 25 plots, 24 on volcanic substrate (Pantelleria: 21, Aeolian Islands: 3), 1 on Hyblaean limestones, all under TM climate (mostly u-a). Among them, 15 undisturbed and 6 burnt were abandoned between 1968 and 1987, 3 (2 undisturbed and 1 burnt) within the last 20 years, and one single plot between 1955 and 1968 and then grazed. The most common vegetation feature is a dense (10 plots) or open (13 plots) shrubland/maquis community; 2 terraces are characterized by patchy vegetation made up of perennial grasses and herbs with 30-50% woody cover. The dominant species are *Cistus* spp., *Pistacia lentiscus*, *Calicotome villosa* (Poir.) Link,

Phillyrea latifolia, *Rubus ulmifolius* and *Quercus ilex* L.. The species combination and the patchy habit of vegetation result from a mixture of garrigue (*Cisto-Ericion multiflorae*), open maquis [*Oleo-Ceratonion siliquae* or *Ericion arboreae* (Rivas-Martínez ex Rivas-Martínez, Costa et Izco 1986) Rivas-Martínez 1987] and, sometimes, perennial grassland (mostly *Hyparrhenion hirtae*). This cluster includes mature undisturbed or periodically burnt plant communities of the thermomediterranean belt growing on terraces which have been abandoned long time ago.

All the 6 relevés included in **Cluster 6** have been made on the Aeolian Archipelago, under TM-u-a climate. 5 burnt samples were abandoned at least 20 years ago, 1 grazed plot was abandoned prior to 1955. The plant community pertaining to this cluster is rather uniform: it is characterized by patchy vegetation made up of perennial grasses and/or herbs with woody cover of 15-60%, where the dominant species are *Brachypodium retusum* (Pers.) P. Beauv. and *Cistus* spp. The edapho-climatic context, the structure and the floristic composition of relevés match very well with *Thero-Brachypodion ramosi* Br.-Bl. 1925 communities, already known for the Aeolian Islands, dynamically connected with *Cisto-Ericion multiflorae* garrigues.

Cluster 7 includes 6 sample plots, 5 on vulcanites under TM-u-a (Pantelleria) and 1 on limestones (Palermo Mts) under MM-l-s climate. All the samples were abandoned at least 20 years ago: 3 of them are undisturbed, 3 are burnt. Vegetation structure appears quite uniform: open (1 sample) or dense (5 samples) shrubland/maquis. The dominant species are: *Arbutus unedo* L., *Erica arborea* L., *Erica multiflora* L., *Phillyrea latifolia*, *Quercus ilex*, *Cistus* spp. and *Myrtus communis* L. Concerning the phytosociological treatment of the relevés, those of Pantelleria should be referred to *Quercetalia calliprini* Zohary 1955 and, more precisely, to *Ericion arboreae* (3) or to *Oleo-Ceratonion siliquae* (1), or to *Quercetalia ilicis* Br.-Bl. 1936 em. Rivas-Martínez 1975 and to *Erico-Quercion ilicis* Brullo, Di Martino et Marcenò 1977 (1). The plot of Palermo Mts., which probably clumps together with other plots of this cluster only because it shares some dominant species with them, should be ascribed to *Cisto-Ericion multiflorae*.

Cluster 8 includes 5 relevés made on Aeolian volcanic substrates under TM-u-a climate. All the sampled terraces have been abandoned before 1987 and most of them before 1955; three of them are undisturbed, 1 burnt and 1 grazed. We always observed species-poor, open and dense shrublands/maquis communities with at least 60% of woody cover. The dominant species are *Erica arborea*, *Arbutus unedo*, *Pistacia lentiscus* and *Spartium junceum*. The vegetation of the undisturbed terraces and that of the burnt plot should be referred to *Ericion arboreae*. These plots, which show clear (floristic and structural) links with Cluster 3, are very poor in woody species, probably because past intense human pressure led to the extinction of many forest species on some Aeolian islands; nevertheless, they represent the most mature features of local vegetation.

Cluster 9 includes 21 relevés, 10 made on volcanic rocks (Mt. Etna), 11 on limestones (Hyblaean Plateau: 8, Palermo Mts.: 3), mostly under MM (l-s and l-h) climate. Most of them are grazed fallows of all abandonment ages; four undisturbed plots were abandoned less than 20 years ago. Most part of the plots of this cluster are characterized by herbs with about 10% (rarely less, occasionally up to 30%) of woody cover; we recorded the absolute dominance of nitrophilous annual and biennial herbs. Most part of these plots should be ascribed to *Echio-Galactition to-*

mentosae. Single plots are characterized by the dominance of one perennial herb (*Dactylis glomerata* L., *Dactylis hispanica* Roth, *Asphodelus ramosus* L., *Hyparrhenia hirta*) or by the low cover (10-15%) of one pioneer shrub [*Crataegus monogyna* Jacq., *Rubus ulmifolius*, *Artemisia arborescens*, *Genista aetnensis* (Raf.) DC]. Although if made on different substrates, these relevés probably group together due the strong influence of grazing pressure.

Cluster 10 is represented by one single undisturbed terrace on Etna Mt. volcanic soils under MM-l-h climate, already abandoned between 1968 and 1987. Up to now it is characterized by an evergreen, acidophilous species-poor, open woodland dominated by *Quercus ilex* and *Fraxinus ornus* L., which should be referred to *Erico-Quercion ilicis*.

Cluster 11 includes 15 sample plots on limestones (Palermo Mts.: 8, Hyblean Plateau: 7); 14 of them are subject to MM (l-h: 12, u-s: 2), 1 to TM-u-s climate. 13 burnt terraces were abandoned at least 20 years ago; the other 2 between 1968 and 1987 and are now grazed. This cluster is very uniform, being characterized by perennial grasslands referred to *Avenulo-Ampelodesmion mauritanicae* Minissale 1995. Woody cover never exceeds 20%, while in 12 relevés the dominant species, *Ampelodesmos mauritanicus*, covers more than 60% of the plot (!). This community plays the role of a steady-state on the terraces abandoned long time ago and subject to frequent and intense disturbance (especially fire). If disturbance diminishes, it can evolve toward garrigue (*Cisto-Ericion multiflorae*) and, if it stops at all, even toward closed maquis (*Quercion ilicis* Br.-Bl. ex Molinier 1934 em. Brullo, Di Martino et Marcenò 1977).

Cluster 12 includes 18 relevés, all made on limestones (Palermo Mts.: 10, Hyblaean Plateau: 7), except from one on Etna volcanic soils. 17 of them are subject to MM (mostly l-s), while 1 falls into TM-l-s climate. 14 grazed plots were abandoned at least 20 years ago, 3 burnt plots were abandoned at least 40 years ago, one between 1987 and 2000 and then grazed. The vegetation habit of this cluster is quite heterogeneous: 12 samples correspond to patchy vegetation made up of perennial grasses and/or herbs mostly with woody cover between 30-50%, 4 samples are characterized by open and two by dense shrublands/maquis. The dominant species are *Ampelodesmos mauritanicus*, *Calicotome infesta* (C. Presl) Guss., *Coridothymus capitatus* (L.) Reichenb. fil., *Cistus* spp., *Pistacia lentiscus*, *Erica multiflora*, *Spartium junceum*, *Sarcopoterium spinosum* (L.) Spach. Garrigue subshrubs (*Cisto-Ericion multiflorae*) and/or mantle shrubs (*Pruno-Rubion ulmifolii*) are often mixed with perennial grassland (mostly *Ampelodesmion mauritanicae*), with an often significant cover of nitrophilous annual herbs. Here grazing plays a major role than in cluster 11, and woody plants too. Perhaps the differences between these two clusters, which share many structural and floristic traits, depend upon the nature, the frequency and the time gap before the first occurrence of disturbance.

Cluster 13 includes 2 relevés on Mt. Etna vulcanites: the first, abandoned between 1987 and 2000, is undisturbed and under SM-u-s climate, while the second, subject to a MM-u-s climate, has been abandoned between 1968 and 1987 and then grazed. The two plots have quite a different vegetation habit: both are dominated by herbs, but one of them has a 25% woody cover. The dominant species are *Pteridium aquilinum*, *Quercus pubescens* Willd.s.l. and *Genista aetnensis*. This cluster is quite difficult to interpret: infact, many are the differences between its two relevés

(climate, disturbance status and age of abandonment). Nevertheless, they both share a high number of perennial and annual herbs characteristic of *Molinio-Arrhenatheretea* R. Tx. 1937 and *Stellarietea mediae*, respectively. There is no doubt that the clear distinction is strongly influenced by the climatic location of its plots.

Cluster 14 includes 3 relevés made on Mt. Etna vulcanite under SM-u-s climate. All these terraces have been abandoned before 1987; two of them are undisturbed, one is grazed. The vegetation is a dense wood or a mosaic of shrubland (40% woody cover) and herbs. The two most mature plots show a very high cover of *Quercus pubescens* s.l.; other dominant species are *Quercus ilex* and/or *Genista aetnensis*. In two relevés *Pteridium aquilinum* shows high cover values (45%). Two plots should be considered as undisturbed closed (pubescent oak) woodland, referred to *Erico-Quercion ilicis*, while the third is significantly disturbed by grazing, as suggested by the high cover of some *Pruno-Rubion* species. These plots are differentiated by the presence of mesophilous plants chacteristic of *Molinio-Arrhenatheretea* meadows and *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937 temperate forests. Cluster 14 shows some floristic and dynamic connections with 13 plots, once again due to bioclimatic constraints.

Discussion

The grouping of relevés within the 14 clusters was exclusively based on their floristic similarity (DCA and TWINSPAN without vegetation strata). The partial overlap of some clusters stimulates some considerations: 1) fire and grazing effects can overlay since they may occur together and certain species show increased cover values as a reaction on both disturbance factors; 2) it is actually impossible to detect few distinct levels of fire frequency and grazing intensity; on the contrary, disturbance level may vary from sample to sample within the same cluster; 3) geological substrate and bioclimate are important factors, but many plants are able to live under many different combinations of these parameters; 4) vegetation is strongly influenced by abandonment age and disturbance status, and each of them plays an opposite role in modelling its structure: these two factors seem to "struggle", so that many plots grouped together within the same cluster and showing quite a similar physiognomy are either recently abandoned/undisturbed or anciently abandoned/disturbed: this "compensation" mechanism is particularly common in the plots referred to Clusters 2, 5 and 13.

The disturbance factors fire and grazing have a major influence on vegetation dynamics. For a better understanding of the underlying mechanisms, a more precise estimate of their intensity and frequency would be helpful. However, these kind of information is often difficult to get. Finally, one can rely only on the grazing intensity directly observed in the field and on information given by local inhabitants. Nonetheless, up to now we obtained these first results:

1. If no disturbance biases succession, then plant communities evolve rather rapidly: for example, already after 30-50 years of abandonment, most part of Pantelleria old fields have been completely colonized by maquis communities (e.g.: Cluster 7; see also Rühl, 2004).

2. The speed of renaturation processes strongly depends upon the presence of dispersal centers (like at Pantelleria, where maquis nuclea are widespread all over the island) and dispersal vectors (birds, mammals) (Rühl, unpubl. data): hence, the highest is their number and density, the speediest is succession.
3. If fire does not occur frequently, it does not alter the structure of vegetation, since most part of Mediterranean shrubs and trees (*Pistacia lentiscus*, *Phillyrea latifolia*, *Erica* spp., *Quercus ilex*, *Arbutus unedo*, etc.) resprout more or less rapidly. This explains the co-occurrence of undisturbed and burnt plots within Clusters 5 and 7. Nonetheless, the length of the time gap between abandonment and the first burning seems to be important: if fire occurs only after old fields have been already colonized by shrubs, they can easily resprout, while if fire occurs before their colonization, vegetation is more likely to be dominated by fire-tolerant species, such as *Hyparrhenia hirta* and *Cistus* spp. (Roy & Sonié, 1992; Litav, 1972), which under undisturbed conditions could not compete with maquis shrubs.
4. If frequent fires occur, secondary succession is blocked, so that vegetation remains for decades in a "steady state", like the *Ampelodesmos mauritanicus* grasslands of Palermo Mts. and Hyblaean Plateau (Cluster 11), the *Cistus* spp. garrigue of Pantelleria (Cluster 5) or the *Brachypodium retusum* grasslands of the Aeolian Islands (Cluster 6).
5. Where grazing is very intense, the steady state may consist of herbaceous plant communities (Cluster 2 on volcanic islands, Cluster 9 elsewhere). Under this disturbance regime, the few woody species which can grow are spiny (like *Calicotome infesta* and *Rubus ulmifolius*) or poisonous (like *Spartium junceum*).
6. With low-intensity grazing or if grazing begins only after a certain time gap of undisturbed succession, woody cover increases. However, the most common shrubs are still grazing-resistant (this is the case of *Crataegus monogyna* and *Pyrus amygdaliformis* Vill. on Hyblaean Plateau) or even grazing-enhanced, like *Artemisia arborescens* and *Spartium junceum* on Aeolian Islands.
7. The cultivated terraces where farmers used to leave oaks growing at the wall base (this was a common practice in Hyblaean and Etna area), only few decades after abandonment are often covered by a nearly continuous tree layer of *Quercus ilex* and/or *Quercus pubescens* s.l.
8. Another factor which influences the pace of succession is exposition (Rühl, Pasta and Schnittler, 2006).
9. It was quite difficult to assess the phytosociological meaning of many relevés characterized by a high cover of *Pteridium aquilinum* and few pioneer (sub)nitrophilous plants, such as *Rubus ulmifolius*, *Artemisia arborescens* and *Spartium junceum*.

This paper actually is the first attempt to study succession processes within Sicilian terraced landscape by using objective investigation tools.

However, the results sound satisfactory only for volcanic islands (Pantelleria and Aeolian Archipelago: see fig. 5); only there, in fact, not only we found the complete

spectrum of the possible combinations between abandonment age and disturbance, but we could also follow undisturbed succession.

On the contrary, it was very difficult to study secondary succession on calcareous Sicilian territories, as they are subject to huge grazing pressure and frequent wildfires: during three years of field investigations we did not manage to find neither one single undisturbed abandoned terrace nor a mature stand on Palermo Mts. and Hyblaean Plateau. As far as we know, on calcareous substrates and under heavy grazing pressure Cluster 9 prevails; when more or less frequent wildfires occur, the typical plant communities correspond to those grouped in Cluster 11, probably to Cluster 12 under intermediate grazing disturbance.

It was even more difficult to interpret Mt. Etna abandoned terraces' dynamism. First of all, it was difficult to find them: even if a large portion of the volcano is terraced, its slopes are devoted to many different agro-pastoral destinations (fruit tree orchards, chestnut and hazelnut coppices and orchards, citrus orchards, olive and pistachio groves, pastures, etc.), so that still cultivated or abandoned vineyards are rarer than expected at first thought. Besides, most part of the terraced areas devoted to wine culture during the last 50 years are still cultivated or have been recently put back into cultivation. Furthermore, the few terraces that we found did not fit perfectly with our goals, as they mostly occupy a different bioclimatic (mostly MM and

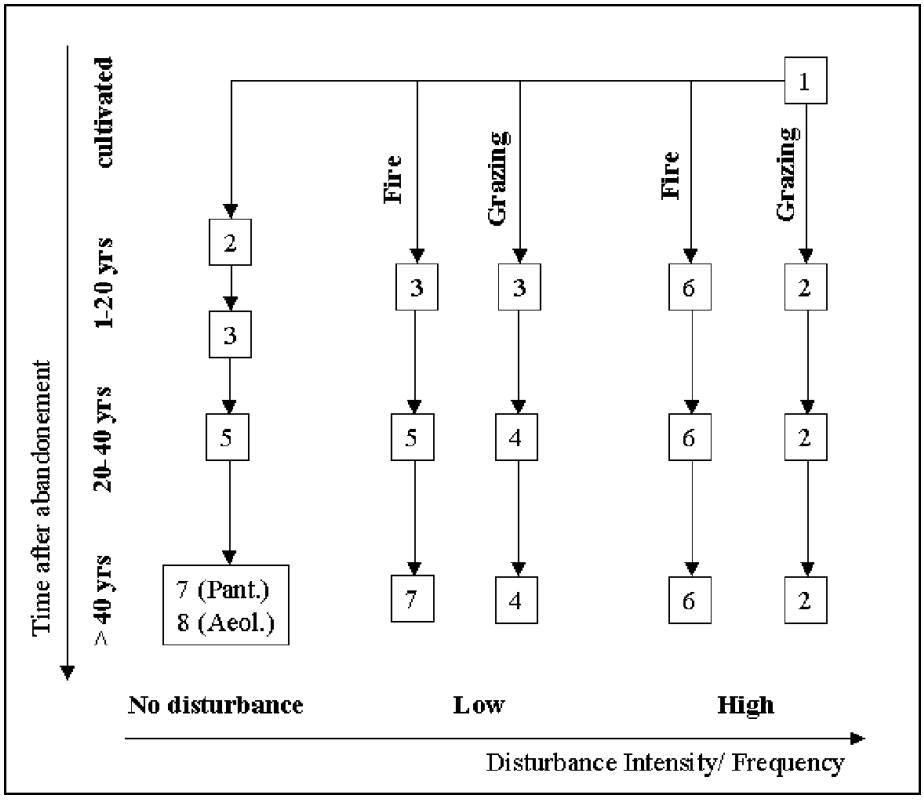

FIGURE 5 - Scheme of the dynamic connection between the different vegetation clusters (boxes) typical to the terraced areas of the Circumsicilian volcanic islands under thermomediterranean climate.

SM) range with respect to those of the other considered areas: very often, in fact, the terraces under TM climate were sacrificed to the urban and suburban development.

More accurate investigations are needed, especially on Mt. Etna. Further studies on terraces' flora (fire- and grazing-dependent presence, dominance and cover; species-richness patterns; phytosociological classification) are still going on and will contribute to a more comprehensive understanding of their dynamics.

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Riassunto

Sono stati effettuati 189 rilievi fitosociologici in cinque aree della Sicilia (tre su substrati vulcanici, cioé l'Arcipelago delle Eolie, Pantelleria e l'Etna, e due su suoli derivanti da rocce carbonatiche, ovvero l'Altipiano Ibleo ed i Monti di Palermo) per indagare sull'andamento della successione secondaria nei vigneti e nei seminativi abbandonati dei territori terrazzati dell'isola. Alla luce delle procedure di analisi multivariata cui sono stati sottoposti i rilievi, il dinamismo della vegetazione considerata appare fortemente condizionato da quattro fattori: bioclima, natura del substrato, età dell'abbandono, (natura, intensità, durata e frequenza del) disturbo. In presenza di nuclei di dispersione di specie legnose in aree contigue, i terrazzamenti indisturbati spesso si evolvono piuttosto rapidamente dando luogo a comunità forestali corrispondenti al "climax" potenziale locale. Un andamento alquanto diverso è stato registrato invece nelle aree che hanno subito - e subiscono tuttora - un disturbo frequente e intenso: in queste condizioni la successione secondaria risulta bloccata e aggruppamenti pauci- o monospecifici di prateria xerica perenne, gariga, mantello e/o formazioni ad erbe annue e bienni possono costituire l'aspetto prevalente e pressocché stabilizzato. La composizione floristica delle comunità vegetali soggette a uno o più fattori di disturbo sembra essere fortemente condizionata dal lasso di tempo che intercorre tra l'abbandono e il primo evento perturbante. Per una migliore comprensione del ruolo ecologico e sindinamico delle comunità vegetali corrispondenti ai 14 cluster individuati si è fatto ricorso ad un approccio "misto" (ecologico, tipologico e fitosociologico): sono stati cioè considerati contemporaneamente non solo i suddetti 4 fattori-chiave, ma anche gli aspetti floristico-strutturali e lo spettro fitocenologico dei cluster stessi. Le ricerche fin qui condotte hanno permesso la costruzione di un modello del dinamismo della vegetazione solo per Pantelleria e le Eolie, mentre l'eccessivo disturbo ha impedito risultati analoghi per gli Iblei e i Monti di Palermo. Per le sue peculiari caratteristiche edafo-climatiche e colturali e per il complesso sviluppo altitudinale e areale del suo territorio terrazzato, infine, l'Etna merita ulteriori indagini.

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